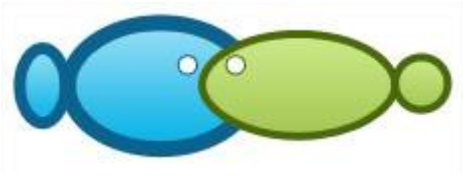

Penaeus merguiensis (De Man, 1888) shrimp exploitation rate in the Arafura Sea, Merauke, South Papua

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Abstract. The moratorium on shrimp fishing in the Arafura Sea is based on the Regulations of the Minister of Maritime and Fisheries Affairs Number 56 of 2014 and Number 2 of 2015, to control shrimp fishing mortality. In nine years of the 2014-2023 moratorium there has been no shrimp fishing permit for fishermen in South Papua. The community has been wanting the opening of shrimp fishing in the Arafura Sea in a 12-mile area of the province. The research objective was to analyze the growth rate, mortality, and exploitation rate of *Penaeus merguiensis* shrimp fishing in the Arafura Sea, Merauke, South Papua, before and after the moratorium. This research used a survey method with systematic random sampling technique. Data collection time: March-May 2011 (before the moratorium) and August 2022 - July 2023 (after the moratorium). Shrimp growth equations before the moratorium were: $Lt = 49.0\ (1\text{-}exp^{-0.7(t\text{-}0.2003)})$ for the male, and $Lt = 52.6\ (1\text{-}exp^{-1.2\ (to\text{-}0.1139)})$ for the female. After the moratorium, the equations were: $Lt = 45.9\ (1\text{-}exp^{-1.2(t\text{-}0.1182)})$ for the male, and $Lt = 58.2\ (1\text{-}exp^{-1.3\ (to\text{-}0.0459)})$ for the female. Shrimp mortalities before the moratorium for the male were $Z = 5.32\ year^{-1}$, $M = 1.47\ year^{-1}$, and $F = 0.72\ year^{-1}$; and for female they were: $Z = 2.97\ year^{-1}$, $M = 1.54\ year^{-1}$, $F = 1.43\ year^{-1}$. After the moratorium, the mortalities for the male were: $Z = 7.24\ year^{-1}$, $M = 1.76\ year^{-1}$, and $F = 5.48\ year^{-1}$, and for the female they were: $Z = 4.18\ year^{-1}$, $M = 1.73\ year^{-1}$, $F = 2.45\ year^{-1}$. Exploitation rates (E) of shrimp before the moratorium were $E = 0.72\ year^{-1}$ and $E = 0.48\ year^{-1}$ for male and female respectively. After the moratorium the rates were $E = 0.76\ year^{-1}$ and $E = 0.59\ year^{-1}$ for male and female respectively. The growth rate of shrimp after the moratorium was greater than before the moratorium. Natural mortality (M) was the highest before the moratorium, and became low after the moratorium, and was dominated by mortality due to fishing (F). The exploitation rate of male shrimp before and after the moratorium was $E > 0.5$ in the overfishing category, and the exploitation rate of female shrimp after the moratorium was in the overfishing category. The results of the study can be used as a consideration for *P. merguiensis* shrimp management policies in Merauke, South Papua.

Key Words: exploitation rate, moratorium, sampling, sustainability.

Introduction. The sustainable potential of Penaeid shrimp in Indonesian waters is 252,302.84 tons $year^{-1}$, while the maximum sustainable yield (MSY) is 201,842.27 tons $year^{-1}$. The resource utilization of Penaeid shrimp in Indonesia was four fisheries management areas (FMAs)categorized in overfishing, five FMAs categorized in saturated fishing, and only two FMAs that were still moderate, namely FMA 714 and FMA 717. The Arafura Sea is in FMA 718 in the saturated fishing category (KKP 2017; Saputra 2019).

The estimated potential for Penaeid shrimp in FMA 718 of the Arafura Sea and its surroundings is 62,842 tons $year^{-1}$ while the MSY is 50,274 tons $year^{-1}$, the utilization rate is 0.84 with fully exploited status (Regulation of the Minister of Maritime and Fisheries Affairs Number 19 of 2022; Wijayanto 2023). Research reports from various sources stated that the Penaeid shrimp utilization level has generally exceeded its sustainable potential (over exploited) (Sumiono 2012; Kembaren & Suman 2013;

Purwanto 2013; Suman & Satria 2014; Hargiyatno et al 2015; Kembaren & Ernawati 2015; Chodrijah & Suman 2017; Saputra et al 2018; Wagiyo at al 2018; Suman et al 2020; Tirtadanu & Chodrijah 2020; Suman et al 2022).

SIPI is the Indonesian Government's policy to limit fishing. Moratorium scales down the fishing license of the ex-foreign vessels by freezing and revoking it. Freezing of SIPI means that the fishing license is no longer valid, so any operation at sea is prohibited. Meanwhile, a revoked SIPI means that the fishing license cannot be extended again when its validity period expires (BRIN 2017). The temporary suspension (moratorium) of the operation of large fishing vessels in Indonesian waters was marked by the Regulation of the Minister of Maritime and Fisheries Affairs Number: 56 of 2014, Regulation of the Minister of Maritime and Fisheries Affairs Number: 57/PERMEN-KP/2014, and followed by Regulation of the Minister of Maritime and Fisheries Affairs Number: 2 of 2015. The first moratorium was implemented from November 2014 to April 15 2015, and the second moratorium was implemented from May to October 2015 (The National Research and Innovation Agency 2017). Furthermore, in Kumparan Bisnis (2018), it was emphasized that there has been no longer a moratorium policy on ex-foreign vessels. Currently, the regulation forces a prohibition on the operation of ex-foreign vessels, which supports a complete ban on foreign capital in the fishing sector. However, at the focus group discussion (FGD) on 22 June 2023 in Merauke, South Papua, which discussed the illegal, unreported and unregulated fishing and fisheries management strategy for *Penaeus merguiensis* shrimp in the Arafura Sea, South Papua, it was confirmed that there has been no issuance of shrimp fishing permits according to the regional authority.

Considering the length of the moratorium on the catching of Penaeid shrimp, which has been going on for approximately nine years from 2014 to 2023, also from the order of the community and regional government (Marine and Fisheries Office) of both provinces and districts to reopen the shrimp fishing permit in the Arafura Sea, based on the Law Number 22 of 1999 concerning Regional Autonomy; Law Number 2 of 2021 concerning Special Autonomy for Papua; the essence of implementing regional autonomy Ghofar (2022), it is important to carry out a study on the analysis of *Penaeus merguiensis* shrimp exploitation rates in the Arafura Sea coastal waters of Merauke, South Papua. This research aimed to analyse the growth rate, mortality, and exploitation rate of *P. merguiensis* shrimp in the Arafura Sea, Merauke, South Papua, before and after the moratorium. The research results can be used as a basis for considering management policies for *P. merguiensis* in Merauke, South Papua.

Material and Method. The research was carried out in the coastal waters of the Arafura Sea, Merauke, South Papua, focusing on three observation stations: A. Naukenjerai District, B. Merauke District, and C. Semangga District, as in Figure 1. The research method used a survey method (Nazir 2003). The shrimp sampling method used systematic random sampling (Saputra et al 2013), where samples were obtained from three collecting traders representing the three observation stations. The number of samples taken was carried out proportionally reflecting the following criteria:

1) If the amount of shrimp production landed at the collecting trader was 1-3 kg, then the number of samples taken was 100% of the amount of production landed;
2) If the amount of shrimp production landed at the collecting trader was less than 50 kg (4-49 kg), then the number of samples taken randomly was 80-6.12% of the amount of production landed;
3) If the amount of shrimp production landed at the collecting trader was 50 kg, then the number of samples taken randomly was 6% of the amount of production landed;
4) If the amount of shrimp production landed by collecting traders was 51-100 kg, then the number of samples taken randomly was 5.9-2% of the amount of production landed.

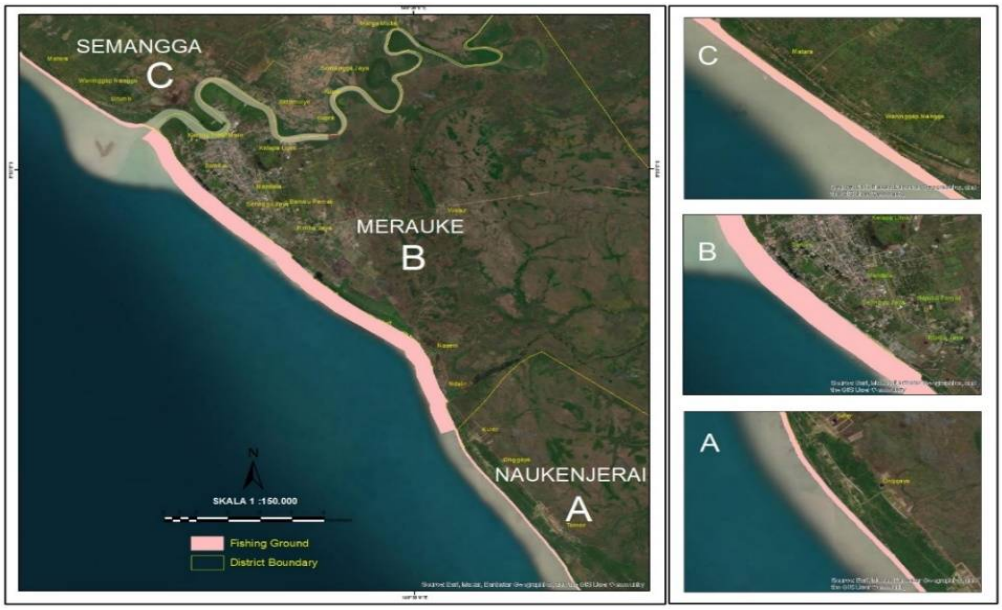

Figure 1. Merauke coastal water research location map.

Primary data on Penaeid shrimp collected: (a) before the moratorium: March - May 2011, and (b) after the moratorium: August 2022 - July 2023. Primary data studied included: carapace length, total length, weight, gonad maturity level and gender (FAO 1998; Treece 2000; Saputra 2008; Gopalakrishnan 2014; Kembaren & Risnawati 2015; Vance & Rothlisberg 2020). The measurement, weighing, and observation of the shrimp samples were done at the Aquatic Resources Management Laboratory, Faculty of Agriculture, Musamus University, Merauke, South Papua.

Data analysis

Growth parameters. The shrimp growth parameters followed the Von Bertalanffy growth model (Sparre & Venema 1998; Saputra et al 2021). The mathematical formula can be written as follows:

$$L_t = L_\infty (1-e^{-K(t-to)})$$

where: L_t = life length t; L_∞= infinity length (asymptotic); K = parameter describing the speed of reaching L_∞; t_o = theoretical age when the shrimp is zero in length; e = natural numbers (exponential).

The estimation of theoretical age (t_o) was carried out using the equation of Pauly (1983):

$$\text{Log } (- t_o) = -0.3922 - 0.2752 \text{ Log } (L_\infty) - 1.038 \text{ Log } (K)$$

The method for determining carapace length (L_∞) and growth rate (K) was estimated using the ELEFAN software contained in the FiSAT II program package.

Mortality rate. The total mortality (Z) rate estimation was studied using the length-converted catch curve method using the FISAT II program package (Pauly 1983; Gayanilo et al 2005). The total mortality formula was as follows:

$$Z = F + M$$

The natural mortality (M) rate was estimated using the formula of Pauly (1983):

$$\text{Log } M = -0.0066-0.279 \text{ Log } + 0.654 \text{ Log } K + 0.4534 \text{ Log } T$$

where: M = natural mortality rate; L = maximum total length; K = growth rate; T = temperature (^oC).

Mortality rate due to fishing (F) was obtained by subtracting the total mortality rate (Z) from the natural death rate (M):

$$F = Z - M$$

Exploitation rate (utilization rate). The exploitation rate (E) was obtained from:

$$E = F / Z$$

The exploitation rate of *P. merguiensis* shrimp followed the classification by Pauly (1984): E value < 0.5 (under fishing); E value = 0.5 (MSY); and E value > 0.5 (overfishing).

Results and Discussion

Growth rate. The growth rate of *P. merguiensis* shrimp in the Arafura Sea, Merauke, South Papua, before and after the moratorium is as shown in Table 1 and Figure 2.

Table 1

Growth comparison of male and female *P. merguiensis* shrimp in the Arafura Sea, Merauke, South Papua, before and after the moratorium

Growth coefficient (K, year)	*Infinity length (L∞, mmCL)*	*Growth coefficient (K, year)*	*Infinity length (L∞, mmCL)*
Before the moratorium		*After the moratorium*	
Male = 0.70	Male = 49.0	Male = 1.20	Male = 45.9
Female = 1.20	Female = 52.6	Female = 1.30	Female = 58.2
Average = 0.95	Average = 50.80	Average = 1.25	Average = 52.05

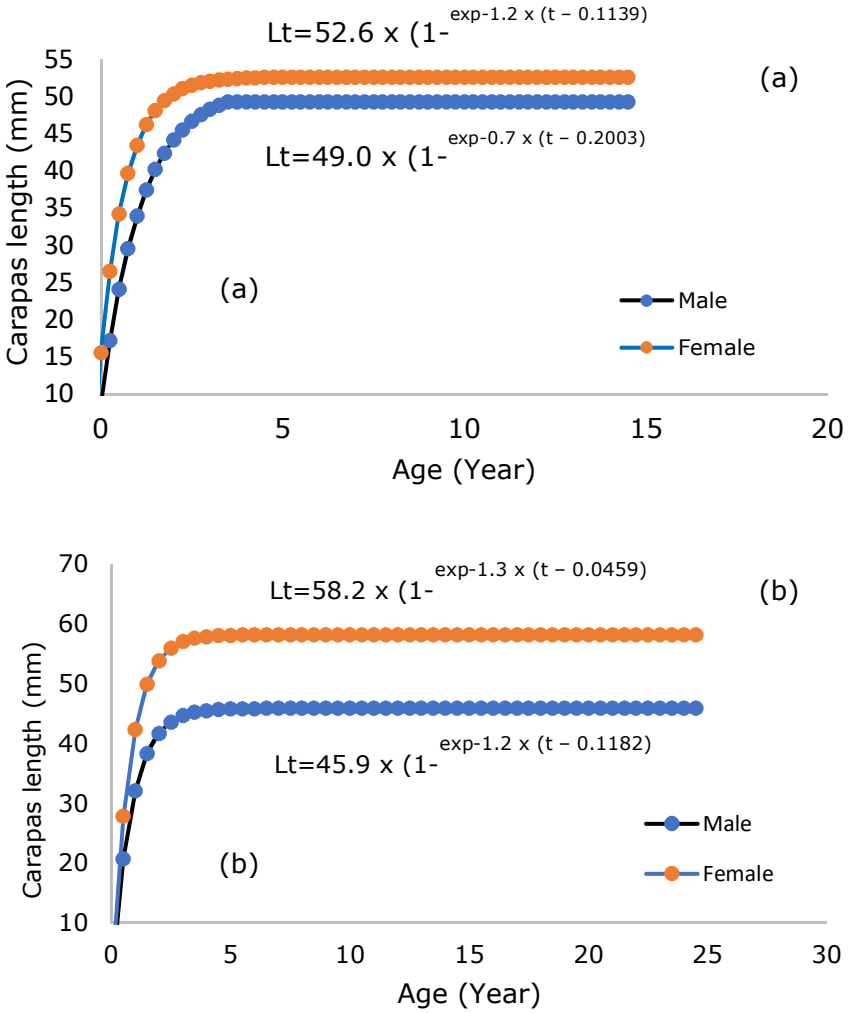

Figure 2. Growth curve of *P. merguiensis* shrimp in the Arafura Sea, Merauke, South Papua: (a) before the moratorium; (b) after the moratorium.

The growth of *P. merguiensis* shrimp before the moratorium was based on the equations Lt = 49.0 ($1\text{-}exp^{-0.7(t-0.2003)}$) for the male, and Lt = 52.6 ($1\text{-}exp^{-1.2\ (to-0.1139)}$) for the female. The growth equations after the moratorium were Lt = 45.9 ($1\text{-}exp^{-1.2(t-0.1182)}$) for the male, and Lt = 58.2 ($1\text{-}exp^{-1.3\ (to-0.0459)}$) for the female. Growth coefficient (K) of male shrimp before the moratorium was 0.7 $year^{-1}$, smaller than the K value of male shrimp after the moratorium, namely 1.2 $year^{-1}$; Saputra et al (2018) obtained the value 1.3 $year^{-1}$, Tirtadanu & Chodrijah (2020) obtained 1.63 $year^{-1}$, and Momeni et al (2018) obtained 1.8 $year^{-1}$. The K value of female shrimp before the moratorium was 1.2 $year^{-1}$, smaller than the K value of female shrimp after the moratorium, namely 1.30 $year^{-1}$. The K value of 1.30 $year^{-1}$ was greater than the research of Saputra et al (2018), but smaller than the research by Tirtadanu & Chodrija (2020), and Momeni et al (2018).

The growth coefficient (K) is a parameter that shows the speed of the shrimp to obtain the maximum infinite length (L∞) value. A larger K value indicates faster shrimp growth (Saputra et al 2018). Suman et al (2022) supported the statement by Gulland (1983) and Naamin (1984) that a K value for *P. merguiensis* shrimp that is greater than or equal to one indicates that this shrimp has a fast growth rate. The lower the K value, the longer it will take to reach the L∞ value (Sparre & Venema 1998). Referring to the average K value, the growth rate of *P. merguiensis* shrimp after the moratorium was 1.25 $year^{-1}$, faster than before the moratorium - 0.95 $year^{-1}$. Effendie (2002) stated that growth is influenced by several factors, including: the amount and size of food available, temperature, dissolved oxygen, water quality, age, and size of fish. Saputra et al (2021) stated that species with high K values have large M, and species with low K values have low M.

The infinite length (L∞) of male shrimp before the moratorium was 49 mm carapace length (CL), greater than the L∞ of male shrimp after the moratorium which was 45.9 mm CL. These two L∞ values are greater than the research of Momeni et al (2018), but smaller than the research of Saputra et al (2013, 2018) and Tirtadanu & Chodrijah (2020). The L∞ of female shrimp before the moratorium was 52.6 mm CL, smaller than the L∞ of female shrimp after the moratorium which was 58.2 mm CL. These two L∞ values were different from other previous studies in Table 2.

The differences in L∞ are caused by several factors, including different food abundance and the influence of environmental conditions at each research location (Efendi 1997 in Nurdin & Kembaren 2015). Saputra et al (2018) stated that the L∞ value depends on the mesh size of the fishing gear used and the location where the shrimp are caught. Referring to the average L∞, and supported by the growth coefficient K, the infinite length of *P. merguiensis* shrimp after the moratorium (average L∞ = 52.05 mm CL) would be achieved more quickly than before the moratorium (average L∞ = 50.80 mm CL).

Table 2

Comparison of growth rate (K) and infinite length (L∞) of *P. merguiensis* shrimp in several waters

Sex	*K year^{-1}*	*L∞, mm CL*	*References*	*Waters*
M	1.30	52.5	Saputra et al (2018)	North coastal of Central Java
F	1.20	57.2		
M	1.63	47.0	Tirtadanu & Chodrijah (2020)	Cilacap waters
F	1.60	63.2		
M	-	60.4	Saputra et al (2013)	Cilacap waters
F	-	63.8		
C	1.00	58.1	Suman et al (2020)	Bengkalis waters and its surroundings
C	1.47	44.6	Wagiyo et al (2018)	Cilacap waters
C	1.30	60.0	Suman et al (2022)	The Arafura Sea, Arafura Islands
C	1.50	60.9	Mollynda et al (2022)	Kendal, Central Java
C	-	29.4	Tirtadanu & Ernawati (2016)	North coastal of Central Java
M	1.80	39.5	Momeni et al (2018)	Persian Gulf waters
F	1.50	50.0		

Notes: M = male; F = female; C = combination between male and female.

Mortality and exploitation rate. Total mortality rate (Z), natural mortality (M), and mortality due to fishing (F) of *P. merguiensis* shrimp before the moratorium are as follows: for male Z = 5.32 year^{-1}, M = 1.47 year^{-1}, and F = 0.72 year^{-1} (Figure 3a); for female Z = 2.97 year^{-1}, M = 1.54 year^{-1}, F = 1.43 year^{-1} (Figure 3b). The total mortality rate (Z) of *P. merguiensis* shrimp, both male and female, was different from previous research (Table 3). The male Z value is greater than the research of Saputra el al (2018), Suman & Prisantoso (2017), and Kembaren & Ernawati (2015), but it is smaller than the research of Momeni et al (2018). The female Z value is smaller than the research of Saputra el al (2018), Kembaren & Ernawati (2015), and Momeni et al (2018), but bigger than Suman & Prisantoso (2017). Based on Table 3, the mortality rate due to fishing (F) is greater than natural mortality (M), except for female *P. merguiensis* shrimp in Cilacap waters, according to research by Suman & Prisantoso (2017).

Total mortality (Z), natural mortality (M), and mortality due to fishing (F) of *P. merguiensis* shrimp after the moratorium are as follows: for male shrimp Z = 7.24 year^{-1}, M = 1.76 year^{-1}, and F = 5.48 year^{-1} (Figure 4a); for female shrimp Z = 4.18 year^{-1}, M = 1.73 year^{-1}, F = 2.45 year^{-1} (Figure 4b). The mortality rate of both male and female *P. merguiensis* shrimp was different from several previous studies (Table 3).

Table 3

Comparison of mortality rates and exploitation rates of *P. merguiensis* shrimp in several waters

Sex	*Total mortality, Z (year)*	*Natural mortality, M (year)*	*Fishing mortality, F (year)*	*Exploitation rate, E (year)*	*References*	*Waters*
M	4.51	1.86	2.65	0.59	Saputra et al (2018)	North coast of Central Java
F	5.36	1.72	3.64	0.68		
C	6.05	1.58	4.47	0.74	Suman et al (2017)	Tanah Laut waters
C	7.50	1.82	5.68	0.76	Chodrijah & Suman (2017)	Tarakan waters
M	2.46	1.09	1.37	0.56	Suman & Prisantoso (2017)	Cilacap waters
F	1.69	1.08	0.61	0.36		
C	3.71	1.34	2.37	0.64	Wagiyo et al (2018)	Cilacap waters
M	4.96	1.68	3.23	0.66	Kembaren & Ernawati (2015)	Cendrawasih Bay
F	3.89	1.74	2.15	0.55		
C	3.79	1.57	2.22	0.59	Suman et al (2022)	Arafura and its surroundings
M	5.90	2.90	3.00	0.49	Momeni et al (2018)	Persian Gulf waters
F	5.70	2.50	3.20	0.56		

Notes: M = male; F = female; C = combination between male and female.

F shows the rate of fishing in these waters, while M can be caused by environmental factors such as temperature, salinity of the waters, also predation and competition factors (Mollynda et al 2022). Research analysis results before the moratorium showed the comparison of the M with F: male shrimp M > F; female shrimp M > F; average M value > F. After the moratorium, comparison of M and F values showed that: male shrimp M < F, female shrimp M < F; average M < F. Before the moratorium, M was greater than F, but after the moratorium, F was greater than M. Saputra et al (2021) stated that the size of M rate really depends on the habitat or environment. The same species occupying different areas can have different mortality rates due to different densities of predators and competitors.

E values of *P. merguiensis* shrimp before the moratorium were: male shrimp = 0.72 year^{-1} (Figure 3a), female shrimp E = 0.48 year^{-1} (Figure 3b). E values of *P. merguiensis* shrimp after the moratorium were: male shrimp = 0.76 year^{-1} (Figure 4a), female shrimp E = 0.59 year^{-1} (Figure 4b). E of *P. merguiensis* shrimp following the criteria by Pauly (1984): E value = 0.5 (MSY), E value > 0.5 (overfishing), E value < 0.5 (underfishing). Based on the results of the analysis above, the E levels of *P.*

merguiensis shrimp before the moratorium were: male shrimp (overfishing), female shrimp (underfishing). After the moratorium, both male and female shrimp were categorized as overfishing. Based on the average value, E level of *P. merguiensis* shrimp before and after the moratorium was overfishing. This exploitation rate was similar to the research by Saputra et al (2018) on the North Coast of Central Java; Suman et al (2017) in Tanah Laut waters; Chodrijah & Suman (2017) in Tarakan waters; Suman & Prisantoso (2017) and Wagiyo et al (2018) in Cilacap waters; Kembaren & Ernawati (2015) in Cenderawasih Bay; and Suman et al (2022) in the Aru Sea and its surroundings (Arafura Sea). However, it was different from the research of Momeni et al (2018) in Persian Gulf waters, where only male shrimp was categorized as underfishing and female shrimp as overfishing. According to Gulland (1971), a stock has reached optimal exploitation if E = 0.5. The use of E = 0.5 as the optimal value for the exploitation ratio of a stock is based on the assumption that the results are balanced if F = M. Wijayanto (2023) said that the crucial issue of sustainability of wild fisheries is related to the concern of food security, both for the world and Indonesia itself. If the problem of overfishing is not resolved, it will threaten the sustainability of fish resources and food security.

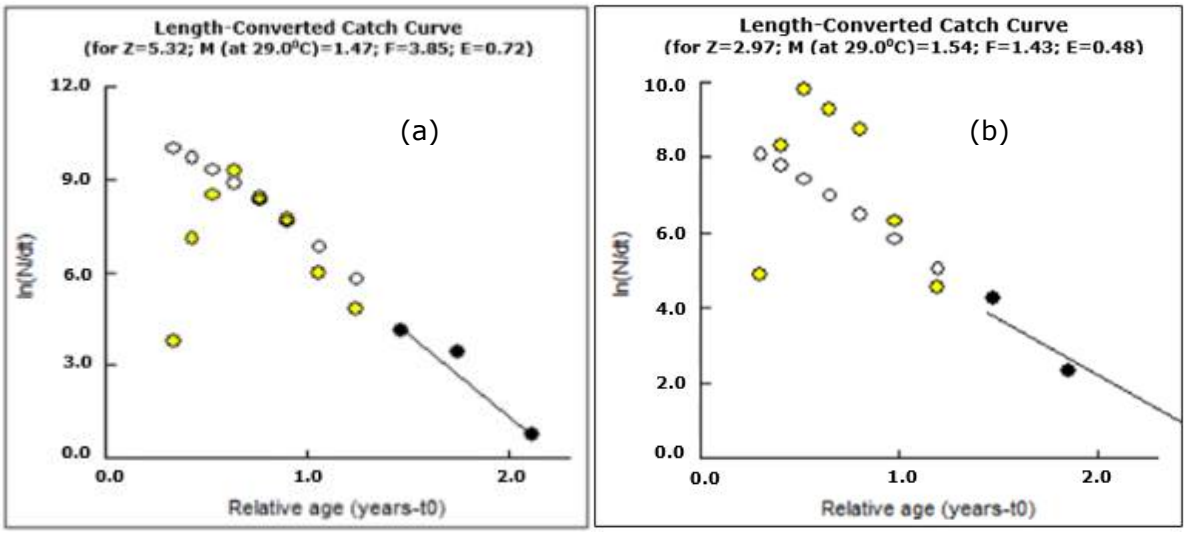

Figure 3. Mortality (Z, M, F) and exploitation rate (E) of *Penaeus merguiensis* shrimp: (a) male, and (b) female before the moratorium.

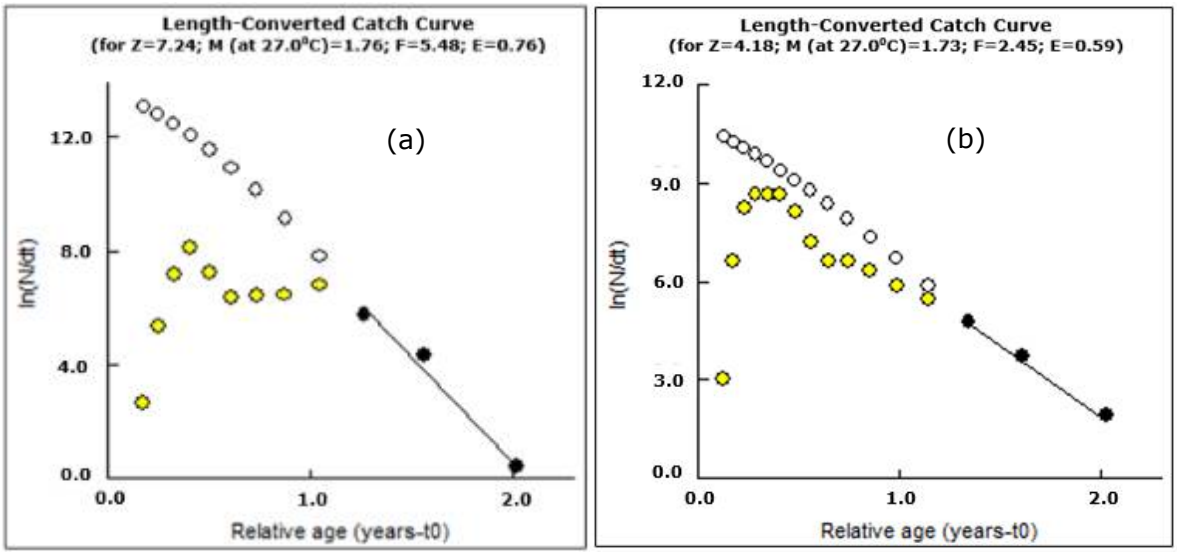

Figure 4. Mortality (Z, M, F) and exploitation rate (E) of *Penaeus merguiensis* shrimp: (a) male, and (b) female after the moratorium.

Conclusions. The average growth rate (K, L∞) of *P. merguiensis* shrimp after the moratorium was greater than before the moratorium (K = 1.25 year^{-1} > 0.95 year^{-1}; L∞ = 52.05 mm CL > 50.80 mm CL). The highest natural mortality (M) occurred before the moratorium, but after the moratorium, mortality became low and was dominated by mortality due to fishing (F). The exploitation rate (E) of male shrimp before and after the moratorium was E > 0.5 in the overfishing category, and the exploitation rate of female shrimp after the moratorium was in the overfishing category. The results of the study can be used as a basis for considering management policies for *P. merguiensis* shrimp in Merauke, South Papua.

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Conflict of interest. The authors declare that there is no conflict of interest.

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